Gravity Power Plants

Next Generation
Pumped Storage Hydro

Jim Fiske

May 2016
The Problem

250,000 MW of new Powerplant capacity per year until 2060 (International Energy Agency)

Didcot Power Station, UK

Expected worldwide power demand increase by 2050:

4,000 Gigawatts!
(60 – 200 GW/Year)

Wind & solar PV cost:
soon < 3¢/kWh

Coal-fueled plants rapidly shutting down
Adding 60-200 GW/Year

- Too Variable
- Too Variable
- Not Variable Enough
Accommodating Variability

Only low-carbon solution: Energy storage

Storage needed in 2050:
80 - 160 GW (U.S.)
310 – 520 GW (worldwide)

*IEA Storage Technology Roadmap 2014
Storage Technologies (log scale)
Storage Technologies (linear scale)

Pumped Storage Hydro

Diagram showing discharge time (hr) vs. rated power (MW) for various storage technologies.
Current Deployment

Worldwide Energy Storage Capacity (MW)

Pumped Storage Hydro (PSH) is currently the only viable bulk storage technology.

Source: Navigant Research (Dehanna, Eller & Embury, 2014) for installed battery capacity by type, and GlobalData (2015) for the pumped-storage hydroelectricity capacity.
PSH Deployment Constraints

Current PSH designs:

- Consume large areas
- Are geographically limited
- Take 10-15+ years to permit & build
- Cost $1–3B

Conventional PSH cannot provide the energy storage needed
The Gravity Power Plant (GPP)

Storing Energy
The Gravity Power Plant (GPP)

Generating Power
GPP Parameters

- Piston diameter: ~20-80 meters
- Shaft depth: 500-1000 meters
- Piston height: 250-500 meters
- Piston material:
  - Rock core (2500kg/m^3)
  - Concrete lining
  - Steel surface
- Piston weight: up to several million tonnes
- Working pressure (500m shaft):
  - 375 meters of head (500 psi)
- Plant sizes from 40 to 1200 MW and larger with 2 to 12 hours of output are feasible

40 MW GPP (30m x 500m) at correct scale
Flexible siting with little land use

Fast permitting

Rapid construction (2-3 years)

Low technical risk – no R&D required

Up to 84% round-trip efficiency

No water consumption after fill

Quiet & invisible

Patents issued in 7 countries and pending in 5 more. Major markets are protected.
Operational Characteristics

- Max power is constant ➔ higher efficiency
- Fast ramping: 0 to max power < 20 seconds.
- Variable power in and out
- Far more flexible than Gas Turbine Power Plants
  - Renewables support
  - Ancillary services
Shaft Excavation

- Vertical conveyor
- Rock bolts and shotcrete
- Drill & blast excavation
Crossrail Project (London)

33m access shaft
Piston Construction

annulus cut using roadheaders
Piston Separation

tunnel cut using roadheader
Piston Separation

Tunnel Under Piston
Install Roof Bolts & Floor

Rock bolts

Steel plate

Concrete
Install Reinforcement

Diagram showing the installation of rebar and steel plate.
Baseplate-Floor Close-up

- Rebar
- Baseplate steel
- Floor steel
Prepare for Grouting
Place Initial Support

Concrete fill
Widen Tunnel

![Diagram of Widen Tunnel]
Repeat Under Entire Piston
Slip-form Final Piston Liner

- Shaft liner
- Steel
- Concrete
- Piston
Completed Piston Baseplate
In parallel: construct power house and penstock

- Power equipment 30 - 40m below ground
- Quiet & invisible
- Easy access for installation & maintenance
- Control room at ground level
GPPs will use conventional power equipment from existing manufacturers.
Francis Type Pump Turbine
Piston Seals

- Low piston speed → low wear
- Lateral piston movement
- Triple redundancy
- Removal for maintenance
- Periodic replacement
- Field-bonded seal elements allow scaling

(not correct scale)
Power Output vs Piston Diameter & Shaft Depth

(Note: Many bigger and deeper shafts already exist)
Prices assume 4-hour plants (4 hours of output at full power)
Includes construction, power equipment, contingencies and fees
Does not include development, substation, transmission interconnect, land, or financing
Potential Power Prices

LCOE ($/kWh)*

*Credit Suisse Model -- Assumes $0.03/kWh off-peak power and $2 or $5/MMBtu Gas

GPPs revolutionize energy storage costs
Current Activities

- Demo project in Weilheim, Germany
- Potential first commercial installation in Bavaria
- Early discussions in North Africa
Summary

- GP will sell or develop, own and operate turn-key GPPs, worldwide, using patented technology.

- GPPs:
  - Remove the siting obstacles of PSH;
  - Use conventional construction techniques;
  - Are superior to conventional PSH and gas turbine power plants;
  - Provide bulk electricity storage at low cost;
  - Can alleviate the grid energy storage problem.